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7. January 2008

Online at <http://mpa.ub.uni-muenchen.de/8627/>
MPRA Paper No. 8627, posted 7. May 2008 07:21 UTC

ON THE EFFICIENCY OF TEAM-BASED MERITOCRACIES

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We thank Amnon Rapoport and Gylfi Zoega for their comments.

Keywords: social stratification, meritocracies, mechanism design, non-cooperative games, experiment, team production.

JEL Classification: C72, C92

We acknowledge support from the Australian Research Council and the German Research Foundation.

ABSTRACT

According to theory a pure meritocracy is efficient because individual members are competitively rewarded according to their individual contributions to society. However, purely individually based meritocracies seldom occur. We introduce a new model of social production called “team-based meritocracy” (TBM) in which individual members are rewarded based on their team membership. We demonstrate that as long as such team membership is both mobile and competitively based on contributions, individuals are able to coordinate a complex and counterintuitive asymmetric equilibrium that is close to Pareto-optimal. Our findings are relevant to many contemporary societies in which rewards are at least in part determined via membership in organizations such as for example firms, and organizational membership is increasingly determined by contribution rather than privilege.

I. INTRODUCTION

Historically, social and organizational stratification has often been based on arbitrary criteria such as gender, race, class, nepotism or cronyism, all of which are quite inefficient since they are unrelated to a person's social contribution, and therefore do not provide optimal incentives to contribute. Examples include caste systems, aristocratic societies¹, societies that still bar women or minorities from full participation, or family businesses that assign positions based on birth or family ties. Contemporary societies however are increasingly becoming meritocracies, helped along by equal-rights movements, and increasing global competition that encourages elimination of slack² (see, e.g., Huyett & Viguerie, 2005). In a pure meritocracy members are rewarded on an individual basis and in proportion to their contribution. Because of the ensuing competition they contribute until the marginal benefit of contributing equals its marginal cost.³ A pure meritocracy is therefore a model of production for purely private goods by relatively isolated agents.

However, societies are made up of organizations. An individual's payoffs in a modern economy are rarely based on individual contribution alone but are to a significant extent disbursed via organizations to which individuals belong, e.g. firms. Their rewards to members are often team-based because **1)** some sought-after organizationally based rewards are simply not divisible such as the work atmosphere, facilities (Burdett & Coles, 1999), or the organization's ability to provide superior co-workers (Booth & Zoega, 2005) or **2)** some important divisible benefits such as corporate health care packages could, at least to some degree, be linked to individual output but doing so would be too complex and

¹ See e.g., pre-revolutionary France.

² See e.g. Singapore, a very successful Asian country by most standards. It seceded from Malaysia in 1965 because it rejected ethnic quotas in the assignment of social and professional roles in favor of a meritocracy. Ethnic quotas persist in Malaysia to this day.

³ Other benefits of such a system include its perceived fairness which engenders broad support and hence, stability, and placing the best suited person into a given position.

costly,⁴ or **3**) shared monetary rewards such as equal-share partnerships, gainsharing schemes or a relatively uniform salary level within a firm are often HR policy because they improve morale (another team good) (Campbell & Kamlani, 1997; Lazear, 1989; Pencavel, 1977) and productivity⁵ (Kruse, 1993; Milgrom & Roberts, 1990). In a market for organizational membership typical of a modern organization-based meritocracy where members are increasingly mobile both socially and geographically, those who contribute more are more likely to be part of organizations where membership offers better rewards, and these rewards are often collective. For example, within and across industries employers vary in their desirability based on the level of tangible and intangible benefits they offer. Similarly, more successful academics cluster in more respected academic units (and share among other things the intellectual stimulation of their workplace, salary level and reputation); among students, better students self-select into teams that get higher grades, or get accepted to schools and universities.⁶

All these examples have the following features in common: **1**) The size of the organizational strata is fixed, at least in the short term, that is, the number of positions in a given organization or set of organizations is limited, and access to the desirable strata is therefore competitive,⁷ **2**) individual inputs are measurable, **3**) once individuals are organizationally stratified based on their contributions, they face a social dilemma with some incentive to shirk with regards to their organization's team product. (For a firm the most obvious team product is revenue, for academics or students it would be, among other

⁴ Other examples in this category include employee development programs, or vacation policies.

⁵ Another example are uniform bonuses, uniform company-wide perks, and other payoffs that are kept equal for the sake of employee satisfaction or group cohesion. For example, the salaries and bonuses of associates in elite New York law firms for example are "in lockstep" both within and across firms (Sorkin, 2007).

⁶ In Bulgaria for example, entry examination grades plus some grades from previous years in middle school are summed up. Students are ranked according to that sum and a fixed number of them enter the country's top high schools, those ranking below go to the second tier, etc..

⁷ Organizational stratification always involves fixed group (stratum) size at least in the short run. Examples include journal space in tier 1 journals, or labor markets in which there are usually a fixed number of jobs available, such as the annual supply of junior positions at top universities. In general, there are usually more "perfect" candidates than positions and a perfect candidate reaches the top stratum with a probability of less than 1.

things, their institution's reputation.) However, **4)** the social dilemma is mitigated by the threat of downward mobility: given mobility with regard to organizational membership, a non-contributor is eventually replaced by a contributor.⁸

A system characterized by features **(1)-(4)** above, which we will henceforth call a "team-based meritocracy" (TBM) is not an ordinary system of clubs in the sense of Buchanan (1965): Rather than examining how features of a team good such as excludability affect its provision level, we focus on how the process of assigning members to teams affects the level of team production. Further, we focus not on isolated groups but on a system of teams, and explore how the team assignment method impacts a society's overall productivity. We find that for the system's overall efficiency contribution-based mobility is crucial. Our results show that is not really detrimental for efficiency that rewards are team-based as long as team assignment is competitively based on contributions and organizational membership is mobile. In such a setting, free-riding loses its significance even if rewards are fully shared on the organizational level, i.e. a meritocracy is purely collective rather than individually based.⁹

Compare a team-based meritocracy to a traditional society in which stratification and organizational membership are often based on biased privilege, such as a society with a caste system, a race or a gender bias, or with an economy where positions in its family businesses are based on family ties. To the extent that such bias is applied, the staffing of the system's cooperative entities is unaffected by the actual contributions of its individual members. Organizational staffing is instead based on irrelevant criteria, ultimately an

⁸ These arrangements have even started to formally apply to immigration: For example, Australia or Britain offer preferential entry for immigrants likely to contribute to society, and a similar program is now being proposed in the EU. Mobility is guaranteed by a trial period before immigrants gain citizenship.

⁹ Kandel & Lazear (1992) present a model where peer pressure, norms and mutual monitoring foster productivity in organizations where output is shared. In our model such internal pressure is not needed since organizational membership is highly mobile and low-performing members get re-grouped into lower-performing units.

“accident of birth” in the sense of Rawls (1971).¹⁰ Such a system of organizational and institutional staffing obviously generates incentives to free-ride since an individual’s contribution has, in the extreme case, no impact at all on his membership in organizational units that vary in their attractiveness to members. It is well known that such societies are far from efficient, that their productivity lags behind modern societies that have become, to a considerable extent, team-based meritocracies, and that precisely because meritocracies are more competitive, they are globally on the rise. Examples include the trend away from family businesses and towards professional management, the disappearance of monarchies, or the abolition of legacy preferences in Ivy League universities.¹¹

To our knowledge, this study is the first to show how team-based meritocracies sustain very high social contributions by nearly all members of the society even though rewards are shared within organizations. We show this with a theoretical model of the TBM mechanism (Section II) and its experimental test (Sections III and IV). For a large society the TBM asymptotically approaches the efficiency of an individually-based meritocracy. At the same time, however, it maintains the benefits that come with team-based, rather than individually tailored, incentives, such as cost-savings and cohesion. Even though the mechanism’s asymmetric, close-to-Pareto-optimal equilibrium is very complex, (Section II) the aggregate of experimental subjects seem to intuitively grasp this socially desirable solution and coordinate it reliably (Section III). This underscores a team-based meritocracy’s practical usefulness and may explain its emergence in the field.

This paper is descriptive, accounting for what is already being observed in the field. It is also prescriptive, since our results show that a team-based meritocracy is a highly

¹⁰ Rawls’ “accident of birth” concept encompasses not only social privilege but also differential ability. We bypass the latter in this paper since our current (introductory) model of the team-based meritocracy assumes that abilities to contribute are equal, and we focus on effort. In the Discussion (Section IV) we refer to an extension of our model so that agents have unequal abilities with regard to public contribution.

¹¹ After WWII, legacy preferences were given less weight in order to increase schools’ intellectual competitiveness; at the same time, ethnicity and gender-related intake criteria were abolished (Karabel, 2005).

efficient and feasible mechanism to elicit high social contributions. In addition, our theoretical analysis also sheds some light on prior experimental results (discussed in Section IV) about the effectiveness of competitive grouping as a means to attenuate what would otherwise be a social dilemma.

II. THEORY

We model a team-based meritocracy (TBM) as a society in which participants are assigned to teams based on their contributions to a public account. The TBM shares some features with the Voluntary Contribution Mechanism (VCM, see e.g. Isaac, McCue & Plott, 1985), which has become a standard model for the exploration of free-riding and which, we will argue, is a good model for a privilege-based society. We now briefly describe the former before adding how a team-based meritocracy differs.

In the VCM, N participants are randomly assigned to G groups of fixed size n . With its random team assignment, the VCM models a society in which grouping into cooperative units is based on arbitrary criteria that are unrelated to output and not under a person's control, such as race or gender. After having been grouped, members each decide simultaneously and anonymously how much of their individual endowment w to keep for themselves, and how much to contribute to a group account. Contributions to the group account are multiplied by a factor g representing the benefits from cooperation (see, e.g., Hamilton, Nickerson & Owan, 2003), before being equally divided among all n group members. In the remainder of this paper, we denote the rate g/n by m . This is the marginal per capita return (henceforth, MPCR) to each group member from an investment in the group account. As long as $1 > m > 1/n$, the VCM game is a social dilemma: efficiency is maximized if all participants contribute fully, but each individual's dominant strategy is to contribute nothing to the group account.

The TBM has a different equilibrium structure because group membership is competitively based on individuals' public contributions. All participants get ranked according to their contributions to the public account. Based on this ranking, they are partitioned into equal-sized teams. For the formal equilibrium analysis of the TBM game (Sections II.A and II.B below) it is important to note that any ties for group membership are broken at random. Finally, individual earnings are computed taking into account to which team a subject has been assigned. All this is common knowledge.

The TBM also differs from the VCM in how society is modeled. In the VCM each arbitrarily composed team exists in isolation. Social mobility is not modeled and in fact, does not exist in a society strictly based upon birth-based privilege. The TBM in contrast is not just about a single, isolated group, but about a society consisting of multiple teams. In the TBM all socially mobile members of a community are linked via a cooperative-competitive mechanism. Through their contribution decisions they compete for membership in stratified teams with potentially different collective output and payoffs. The TBM's equilibrium analysis (below) must therefore extend not just over one group, but over the multiple groups of an organizationally stratified society.

The TBM has a close to Pareto-optimal equilibrium: In contrast to the VCM with its dominant strategy equilibrium of non-contribution by all, the TBM has two¹² pure-strategy equilibria, which differ in efficiency.¹³ One of the equilibria is non-contribution by all, which underscores that the TBM game has some social dilemma properties. Section II.B however shows that with the introduction of competitive team assignment, the social dilemma property is much attenuated. The TBM has a second, asymmetric pure strategy

¹² See the Theorem in Section II.B for rare borderline cases in which there are only one or even three.

¹³ Additionally and depending on the parameters, there exist mixed-strategy equilibria. They are beyond the scope of this paper since: **1)** they are intuitively implausible in a game where there is no stringent need to play unpredictably (see, e.g., Kreps, 1990, pp. 407-410; Aumann, 1985, p. 19). **2)** even in situations where a unique equilibrium in mixed strategies would require that players keep each other guessing, it is usually beyond players' abilities (see e.g., Walker & Wooders, 2001; Brown & Rosenthal, 1990; Erev & Roth, 1998). **3)** in the TBM's experimental test subjects clearly play a pure strategy equilibrium (See Section III.B).

equilibrium that is very close to Pareto optimal, and where almost all participants contribute their entire endowment and only few contribute nothing. Section II.B makes it obvious that this near-efficient equilibrium is complex and counterintuitive. Yet this equilibrium is very reliably coordinated in experimental tests (see Section III).

II.A Formal Definition of the TBM

A team-based meritocracy (TBM) is defined as a game with N players. As in the VCM, each player $i = 1, \dots, N$ has an endowment $w > 0$, makes a contribution $s_i \in [0; w]$ to a public account, and keeps the remainder $(w - s_i)$ in her private account. It follows that the contribution s_i completely characterizes a player's strategy. After their investment decisions, all players are ranked according to their public contributions and divided into G groups of equal size n ($G = N/n$). Note that ties are broken at random. The n players with the highest contributions are put into group 1; the n players with the next highest contributions are put into group 2, and so on. Without loss of generality, let $s_1 \geq s_2 \geq \dots \geq s_N$, i. e. group 1 consists of players 1 to n , group 2 of players $(n + 1)$ to $2n$ and so on. Payoffs are computed after players have been grouped this way, including the random resolution of ties. Each player's payoff π_i consists of the amount kept in her private account, plus the total public contribution of all players in the group she has been assigned to, multiplied by the MPCR $g/n = m \in (1/n; 1)$:

$$\pi_i = w - s_i + m \sum_{j=i - [(i-1) \bmod n] + n - 1}^{i - [(i-1) \bmod n]} s_j$$

II.B. Deriving the TBM's equilibria

Observation 1: Obviously, the strategy profile $s_1 = s_2 = \dots = s_N = 0$ is an equilibrium.

Since $m < 1$, no player can profit from contributing a strictly positive amount to the group account if all others give zero.

In the remainder of this section we derive the alternative Pareto dominant equilibria, which are much more complex. We start by assuming that an equilibrium with positive contributions exists and describe its general characteristics in Observation 2. This is followed by a theorem that specifies all pure strategy equilibria, and the criteria for the existence and uniqueness of Pareto dominant near-efficient equilibria.

Observation 2: If an equilibrium with positive contributions exists, each player contributes either zero or her entire endowment w . Moreover, the number of players who contribute their entire endowment is larger than $N - n$.

We break the proof of Observation 2 into four Lemmas and prove each of them separately. To start with, consider the case in which some players make strictly positive contributions. Let $h = \max_i \{s_i \mid i = 1, \dots, N\}$ denote the highest contribution, H the set of players contributing h (i.e. $s_i = h \forall i \in H$), and $b = |H|$ the number of players contributing h .

Lemma 1. If some strategies are positive, then in equilibrium $b > n$ and $(b \bmod n) > 0$, i.e. a high contributor $i \in H$ will be grouped with positive probability with some other player(s) who contribute(s) less than she does.

Proof. (Clearly, $b < N$, else each player could profit from unilaterally changing her contribution from h to zero.) If $b \bmod n$ were zero, player i , who at present contributes h , could reduce her contribution by a small ε and still remain grouped exclusively with high contributors. By the same logic, b must be larger than n .

■

Lemma 2: When some strategies are positive in equilibrium, the highest contribution h cannot be smaller than w .

Proof: We know from Lemma 1 that a high-contributor $i \in H$ is grouped with positive probability with at least one player who contributes less than h . Her expected payoff $E\pi_i(h)$ is smaller than $w - h + m n h$. Assume h were smaller than w and let $\Delta := w - h + m n h - E\pi_i(h)$ ($\Delta > 0$). Let player i increase her contribution from h to $h' := \min \{h + \Delta / (2 (1-m)); w\}$. Then, player i will be grouped with only high contributors with certainty. Denote her expected payoff by $E\pi_i(h')$.¹⁴

$$\begin{aligned} E\pi_i(h') &= w - h' + m(n-1)h + mh' \\ &\geq w - h - \frac{\Delta}{2-2m} + mn h - mh + mh + m \frac{\Delta}{2-2m} = w - h + mn h - \Delta / 2 \\ &> w - h + mn h - \Delta = E\pi_i(h). \end{aligned}$$

Thus, contributing h' rather than h makes player i better off. Consequently, in equilibrium the highest positive contribution cannot be smaller than w .

■

Lemma 3: When some strategies are positive in equilibrium, there cannot be any player j who contributes s_j with $0 < s_j < w$.

Proof: According to Lemma 2, if some strategies are positive the highest contribution is w . Moreover, the number b of players contributing w is larger than n (Lemma 1). Define $b' := (b \bmod n)$ and consider player j whose contribution $s_j > 0$ is the maximum of all contributions smaller than w ($j \notin H$). Assume first that there are no ties with respect to the group membership of player j . Then player j could contribute slightly less and remain in that same group with certainty. This cannot be equilibrium. If, on the other hand, we allow for player j being tied for group membership, then with probability p she will be in a group in which s_j is the highest contribution. Only with probability $(1-p)$, will she be in a group in

¹⁴ The weak inequality “ \geq ” in the second line holds strictly (“ $>$ ”) if $h' = w$. If $h' = h + \Delta / (2 (1-m))$ it holds with equality (“ $=$ ”).

which $(n-b')$ players contribute s_j and b' players contribute w . Her expected payoff is therefore:

$$\begin{aligned} E\pi_j(s_j) &\leq w - s_j + p m n s_j + (1-p)m((n-b')s_j + b'w) \\ &= w - s_j + m(n-b')s_j + mb'w - pmb'(w - s_j). \end{aligned} \quad (1)$$

If player j increased her contribution to $s_j' = \min\{s_j + 1/2 pmb'(w - s_j)/(1-m); w\}$, she would be in a group with a higher total contribution with certainty. Her alternative payoff $E\pi_j(s_j')$ can be estimated with respect to a lower bound by¹⁵

$$\begin{aligned} E\pi_j(s_j') &\geq w - s_j - \frac{1}{2} pmb' \frac{w - s_j}{1-m} + m \left((n-b')s_j + \frac{1}{2} pmb' \frac{w - s_j}{1-m} + b'w \right) \\ &= w - s_j - \frac{1}{2} pmb' \frac{w - s_j}{1-m} (1-m) + m((n-b')s_j + b'w) \\ &= w - s_j - \frac{1}{2} pmb'(w - s_j) + m((n-b')s_j + b'w). \end{aligned} \quad (2)$$

The difference $E\pi_j(s_j') - E\pi_j(s_j)$ is:

$$E\pi_j(s_j') - E\pi_j(s_j) \geq \frac{1}{2} pmb'(w - s_j) > 0. \quad (3)$$

Thus, player j would profit from unilaterally deviating by increasing her contribution s_j , hence this cannot be an equilibrium.

■

Lemma 4: In any equilibrium with positive, contributions, the number $z := N - b$ of players contributing zero is smaller than n .

Proof: It was shown above that in equilibrium $(b \bmod n) > 0$. Consequently, $((N - b) \bmod n) > 0$ as well. If z were larger than n , then any zero contributor could increase her payoff by contributing some small ε and become with certainty a member of the mixed group, in which some members contribute their entire endowment w . In this case her expected payoff

¹⁵ Again, the weak inequality “ \geq ” holds strictly (“ $>$ ”) if $s_j' = w$.

is clearly higher than if she were grouped with these same players only with some probability $p < 1$.

■

Observation 2 follows immediately from Lemmas 1-4.

Theorem: If $m < \frac{N-n+1}{Nn-n^2+1}$, the only equilibrium of the TBM is all players contributing

nothing. If $m \geq \frac{N-n+1}{Nn-n^2+1}$, the TBM has, additionally, a near-efficient equilibrium in

which all but $z < n$ players contribute their entire endowment w and only the remaining z players contribute nothing. z is the integer between a lower bound l and an upper bound u where

$$l := \frac{N-mN}{mN-mn+1-m} \quad \text{and} \quad u := 1 + \frac{N-mN}{mN-mn+1-m}$$

In general, this near-efficient equilibrium is unique (and strict).¹⁶ As the number of groups G increases, the range of MPCRs m , for which a near-efficient equilibrium exists, converges to the interval $(1/n, 1)$.

Only if $\frac{N-mN}{mN-mn+1-m}$ is an integer strictly smaller than $n-1$, there exist two equilibria

involving full contributions, and the number of full contributors in them differs by one.

Proof. Consider the case in which b ($b > N-n$) players contribute fully to the group account and the remaining $z = N-b$ players contribute zero ($z \in \{1, 2, \dots, n-1\}$). In order to identify *all* equilibria that satisfy the characteristics stated in Observation 2, it now remains to show for which b (or z) no full contributor has an incentive to change her contribution to zero, and no zero-contributor has an incentive to change her contribution to w . Denote the

¹⁶ Of course, z actually characterizes a set of equilibria. Even if the structure is unique there are $\binom{N}{z}$ combinations in which z players contribute nothing and $(N-z)$ players contribute fully.

expected payoffs of a full and a zero-contributor by $E\pi_b(w)$ and $E\pi_z(0)$, and the respective alternative expected payoffs of a full contributor unilaterally deviating to zero and a zero-contributor deviating to contributing w by $E\pi_b(0)$ and $E\pi_z(w)$. These payoffs are as follows:

$$\begin{aligned} E\pi_b(w) &= \frac{n-z}{N-z}m(n-z)w + \frac{N-n}{N-z}mnw \\ E\pi_z(0) &= w + m(n-z)w \\ E\pi_b(0) &= w + m(n-z-1)w \\ E\pi_z(w) &= \frac{n-z+1}{N-z+1}m(n-z+1)w + \frac{N-n}{N-z+1}mnw \end{aligned} \quad (4)$$

and in all equilibria that involve positive contributions the following must hold:

$$z \in \{1, 2, \dots, n-1\} \text{ and}$$

$$\begin{aligned} E\pi_b(w) &\geq E\pi_b(0) \\ \Leftrightarrow \frac{n-z}{N-z}m(n-z)w + \frac{N-n}{N-z}mnw &\geq w + m(n-z-1)w \\ \Leftrightarrow m(n-z)^2 + mn(N-n) &\geq (1+mn-mz-m)(N-z) \\ \Leftrightarrow -mnz &\geq N-z-mNz-mN+mz \\ \Leftrightarrow z(mN-nm+1-m) &\geq N-mN \\ \Leftrightarrow z &\geq \frac{N-mN}{mN-mn+1-m} \end{aligned} \quad (5)$$

and

$$\begin{aligned} E\pi_z(0) &\geq E\pi_z(w) \\ \Leftrightarrow w + m(n-z)w &\geq \frac{n-z+1}{N-z+1}m(n-z+1)w + \frac{N-n}{N-z+1}mnw \\ \Leftrightarrow (1+mn-mz)(N-z+1) &\geq (n-z+1)^2m + (N-n)mn \\ \Leftrightarrow N-z+1-mnz + mn - Nmz + mz^2 - mz &\geq (n^2 - 2nz + 2n + z^2 - 2z + 1)m - mn^2 \\ \Leftrightarrow N-z+1-mNz &\geq (-nz + n - z + 1)m \\ \Leftrightarrow (mN - mn + 1 - m)z &\leq N - mn + 1 - m \\ \Leftrightarrow z &\leq \frac{N - mn + 1 - m}{mN - mn + 1 - m} \\ \Leftrightarrow z &\leq 1 + \frac{N - mN}{mN - mn + 1 - m} \end{aligned} \quad (6)$$

Thus, the terms

$$l := \frac{N - mN}{mN - mn + 1 - m} \quad \text{and} \quad u := 1 + \frac{N - mN}{mN - mn + 1 - m} \quad ,$$

respectively, constitute a lower and an upper bound of z .

Since $z \in \{1, 2, \dots, n-1\}$, equilibria with positive contributions only exist if $l \leq n-1$ and $u \geq 1$.

The difference $u - l$ between the upper and the lower bound of z is exactly one. Thus, the interval $[l, u]$ contains at least one integer; it contains exactly two integers if and only if both l and u are (feasible) integers.

Also note that since $m < 1$

$$u = 1 + \frac{N - mN}{mN - mn + 1 - m} > 1 + \frac{N - N}{mN - mn + 1 - m} = 1. \quad (7)$$

Thus, the upper bound u does not impose a restriction on the existence of an equilibrium with full contributions. However, for the lower bound l one needs to ensure that

$$\begin{aligned} n-1 \geq l &= \frac{N - mN}{mN - mn + 1 - m} \\ \Leftrightarrow mNn - mn^2 + n - 1 + m &\geq N \\ \Leftrightarrow m &\geq \frac{N - n + 1}{Nn - n^2 + 1} \end{aligned} \quad (8)$$

Note that from (8) we have¹⁷

$$m \geq \frac{N - n + 1}{Nn - n^2 + 1} > \frac{N - n + 1}{Nn - n^2 + n} = \frac{1}{n} \quad (9)$$

It can therefore be seen that equilibria with positive contributions do not exist for all $m > 1/n$ (or for all $g > 1$). However, the threshold condition for m is rather weak in the sense that

the threshold $\frac{N - n + 1}{Nn - n^2 + 1}$ in (9) converges to $1/n$ as $G \rightarrow \infty$. To see this, rewrite

$$\frac{N - n + 1}{Nn - n^2 + 1} \text{ as } \frac{Gn - n + 1}{Gn^2 - n^2 + 1}. \text{ Its limit computes to } \lim_{G \rightarrow \infty} \frac{Gn - n + 1}{Gn^2 - n^2 + 1} = \frac{1}{n}. \text{ Moreover, if the}$$

group size n increases, the threshold converges to zero, i.e. $\lim_{n \rightarrow \infty} \frac{Gn - n + 1}{Gn^2 - n^2 + 1} = 0$. So, the

¹⁷ The inequality is strict because $n > 1$.

range of MPCRs for which a near-efficient equilibrium exists converges to the interval (0, 1).

■

To summarize this section, an equilibrium of a TBM has the structure that either no player contributes anything to the group account or that $z < n$ players contribute nothing and the remaining $N - z$ players contribute their entire endowment. Note that in a near-efficient equilibrium, there is always exactly one mixed group consisting of full contributors and non-contributors, while all other groups consist of contributors only. This implies that in equilibrium a player who contributes fully will be grouped together with non-contributors with some positive probability.

II.C Properties of the near-efficient equilibrium

Increases in a society's scale and scope. We now examine how the TBM's near-efficient equilibrium is affected by changes in a society's size or scale. Such increases may be due to population increase or economic integration such as the removal of trade barriers. Size increases may or may not go hand in hand with increases in the scale of organizations. We show that the TBM's near-efficient equilibrium is often much more efficient, and never significantly less efficient, the larger the society's size or scale. In many cases, if the society is large, the TBM asymptotically approaches the full efficiency traditionally associated with individually based meritocracies.

We report effects of changes in the number of groups, the group size, and the parameter g , which represents the gains from cooperation. Note that if n increases, the MPCR $m = g/n$ and g cannot be kept constant at the same time. Since both m and g affect incentives in a game with some social dilemma properties (Isaac & Walker, 1988), we

additionally examine a simultaneous increase of both n and g , that is, an increase in organizational scale while keeping the MPCR m constant.

Increases in G , the number of teams. The Pareto-dominant equilibrium's relative efficiency (measured by $\sum_{i=1}^N s_i / Nw$) increases if more teams of size n join the society, because z , the number of zero-contributors in the near-efficient equilibrium, does not grow with G . If G becomes very large, the equilibrium's relative efficiency asymptotically approaches the efficiency of an individually based meritocracy. Formally stated: .

Lemma 5: z is non-increasing in G , and converges quickly to $\left\lceil \frac{1-m}{m} \right\rceil$ ¹⁸ as G becomes large.

Proof: The lower bound of z is

$$l = \frac{N - mN}{mN - mn + 1 - m} = \frac{nG - mnG}{mnG - mn + 1 - m} . \quad (10)$$

The derivative of this lower bound with respect to G computes to

$$\frac{dl}{dG} = -\frac{n(1-m)(mn-1+m)}{(mnG - mn + 1 - m)^2} < 0. \text{ Thus, both the lower and the upper bound of } z \text{ are}$$

strictly decreasing and the number of zero-contributors cannot be increasing in G . Further, reformulate l as follows:

$$l = \frac{nG - mnG}{mnG - mn + 1 - m} = \frac{1-m}{m} \frac{G}{G - 1 + \frac{1-m}{mn}} . \quad (11)$$

It can be seen that l converges to $(1-m)/m$ if G grows to infinity. Recall that the number of non-contributors is the smallest integer at least as large as l .

■

¹⁸ The symbol $\lceil x \rceil$ refers to the smallest integer which is not smaller than x .

Variations in g , the benefits from cooperation. Increasing g raises the payoff from contributing and eventually lowers z and increases efficiency.¹⁹

Lemma 6: The number z of zero contributors in a near-efficient equilibrium is non-increasing in g and—depending on g —can be any value of the set $\{1, 2, \dots, n-1\}$;

Proof: Since $m = g/n$, the lower bound can be reformulated as follows:

$$l = \frac{N - mN}{mN - mn + 1 - m} = \frac{nG - gG}{gG - g + 1 - \frac{g}{n}}$$

The first derivative with respect to g is $\frac{dl}{dg} = -\frac{n^3 G(G-1)}{(gnG - gn + n - g)^2} < 0$, i.e.

the lower and upper bound l and u are strictly decreasing in g . Since $u - l = 1$, the integer z

$\in [l; u]$ is non-increasing in g . Moreover, if $m = \frac{g}{n} = \frac{N - n + 1}{Nn - n^2 + 1}$ (i.e. $g = \frac{N - n + 1}{N - n + 1/n}$),

which is the lowest m for which a near-efficient equilibrium exists (see Theorem), then $z =$

$l = (n - 1)$. If, on the other hand, $g = n$ so that $m = 1$, i.e., both m and g take on their

maximum values, then $z = u = 1$. Thus, as g grows from $\frac{N - n + 1}{N - n + 1/n}$ to n , the number of

zero contributors decreases from $(n - 1)$ to 1.

■

Increases in n , the team size (g is kept constant). If n increases while all other parameters are constant, the MPCR $m = g/n$ decreases. In other words, the opportunity cost of making a public contribution goes up while the payoff if everybody cooperates, gw , stays the same. This occurs in the field if the size and scale of a society increase, but without returns to scale. z , the number of non-contributors in the near-efficient equilibrium increases with this. However, the ratio z/n changes very little and converges to a constant.

¹⁹ If $g > n$, the dominant strategy equilibrium is that everyone contributes. Also note that certain changes in g can affect the existence of equilibria with positive contributions, see the Theorem.

This means that even if the MPCR decreases radically due to an increase in n with no concomitant increase in g , the relative efficiency $\sum_{i=1}^N s_i / Nw$ of the Pareto dominant equilibrium is maintained as n goes to infinity. Formally,

Lemma 7: Keeping g constant, the number z of zero contributors in a near- efficient equilibrium is non-decreasing in the group size n , and z/n converges to $\left\lceil \frac{G}{gG - g + 1} \right\rceil$ as $n \rightarrow \infty$.

Proof: The derivative of the lower bound l with respect to n is

$$\frac{dl}{dn} = G \frac{[gn^2(G-1) + (n-g)^2]}{(gnG - ng + n - g)^2} > 0. \text{ Thus, both the lower and the upper bound of } z \text{ are}$$

strictly increasing in n , and the number of zero-contributors is non-decreasing in n . The

$$\text{ratio } l/n \text{ can be written as } \frac{G(n-g)}{ngG - ng - g + n}, \text{ and } \lim_{n \rightarrow \infty} \frac{G(n-g)}{ngG - ng - g + n} = \frac{G}{gG - g + 1} \text{ so}$$

the proportion of zero contributors z/n converges to $\left\lceil \frac{G}{gG - g + 1} \right\rceil$ as $n \rightarrow \infty$.

■

Joint increase in the team size n and in g , the benefits from cooperation (constant MPCR). Often an increase in organizational scale n increases returns to scale (Chandler, 1996). A simple way to model this is to increase both n and g so that the MPCR m , is constant. In this case z , while non-decreasing, quickly converges to a constant. Therefore, as n approaches infinity the relative efficiency $\sum_{i=1}^N s_i / Nw$ of the near-efficient equilibrium asymptotically approaches 100%. Formally:

Lemma 8: If m is constant, in a near- efficient equilibrium z is non-decreasing in n , but

with increasing n converges quickly to $\left\lceil \frac{1-m}{m \frac{G-1}{G}} \right\rceil \approx \left\lceil \frac{1-m}{m} \right\rceil$ if G is also large.

Proof: The derivative of l with respect to n is $\frac{dl}{dn} = G \frac{(1-m)^2}{(mnG - mn + 1 - m)^2} > 0$. Thus, both

z 's lower bound l and its upper bound u are strictly increasing in n and the number of zero-contributors is non-decreasing in n . Further, reformulation of l yields:

$$l = \frac{nG - mnG}{mnG - mn + 1 - m} = \frac{1-m}{m - \frac{m}{G} + \frac{1-m}{nG}} \xrightarrow{n \rightarrow \infty} \frac{1-m}{m \frac{G-1}{G}} \quad (12)$$

This concludes the comparative statics section. We now address one more property of the TBM which may impact behavior in the mechanism's experimental test (Section III), and in the field.

Stability of contributor payoffs if others deviate from the near-efficient equilibrium

The equilibrium of non-contribution by all is inefficient but safe: payoffs can never be negatively affected by deviations of others. In the near-efficient equilibrium strategic uncertainty impacts the full contributors since obviously, a non-contributor always earns at least w . The uncertainty is compounded by the fact that one among $\binom{N}{z}$ possible asymmetric strategy profiles needs to be coordinated for this particular equilibrium to emerge with precision. The exact size and direction of the impact of deviations by others on the earnings of a full contributor in what would otherwise be a near-efficient equilibrium profile depends on z , n , G , the number of deviators from full contribution d where $1 \leq d \leq (N-z-1)$, and the amount of their deviation $\delta \in (0, w]$.

A desirable feature of the TBM as a mechanism is that depending on d and δ , the impact of downward deviations by others on full contributor earnings is often only mildly negative, sometimes even positive. Figure 1 illustrates this with an example where $w=100$, $n=10$, $N=100$, $MPCR=g/n=m=0.3$, $\delta = 50$ or $\delta = 100$, and d ranges from 1 to $(N - z - 1)$. The figure illustrates that the impact of strategic uncertainty in a near-efficient equilibrium on the payoffs of those who contribute fully is mitigated by competitive stratification, even if d becomes large. This fact should facilitate the coordination of the payoff-dominant equilibrium in practice since it reduces full contributors' "fear" (Rapoport & Eshed-Levy, 1989).

III. EXPERIMENTAL TEST

Refined by a payoff dominance criterion in the sense of Harsanyi & Selten, 1988, the TBM has a clear equilibrium prediction:²⁰ an asymmetric, near-efficient equilibrium should arise since "commonly preferred" (p. 81). The payoff dominance principle however is not the sole method of equilibrium selection, and not uncontested (see, e.g., Binmore, 1989; Aumann, 1988; Crawford & Haller, 1990; Harsanyi, 1995; Van Damme, 2002). It is therefore desirable to triangulate such a theoretical prediction with an empirical test of equilibrium selection for specific games. Does the TBM's contribution-based team assignment indeed induce participants to coordinate the payoff-dominant equilibrium, asymmetric and counterintuitive as it is?

²⁰ Due to the symmetry of the players and the asymmetric structure of the equilibrium it cannot however, predict a unique strategy profile $\{s_1, s_2, \dots, s_N\}$.

III.A METHOD

Design and participants

The TBM was examined under $MPCR = g/n = 0.5$ and $MPCR = g/n = 0.3$ in a balanced design.²¹ Changes in g affect the TBM equilibrium (see Lemma 6). Hence, different MPCR conditions allow **1)** an empirical test of Lemma 6 and **2)** identification of possible behavioral MPCR effects unrelated to the equilibrium, similar to what has been found in the VCM (see, e.g., Isaac & Walker, 1988; Gunnthorsdottir, Houser & McCabe, 2007).

Under each MPCR condition, there were four experimental sessions with twelve participants each, 96 total. Participants were undergraduates at a large US university. They were recruited from the general student population for a two-hour experiment with payoffs contingent upon the decisions they and other participants made during the experiment.

Procedure

Each participant received a \$7 show-up fee, and was privately paid her experimental earnings at the end of the experiment. Participants were seated at computer terminals separated by blinders. There were 80 decision rounds, but subjects were not told their number. At the beginning of each decision round, each subject received one hundred tokens to privately and anonymously invest (in integer amounts)²² in either a private account, which returned one token for every token invested to that subject alone, or a public account, which returned tokens at the specified MPCR to everyone in her group including herself. See Appendix B for the written instructions.

²¹ Gunnthorsdottir, Houser & McCabe (2007) use a similar game in a ten-round experiment, but the structure of their game is not common knowledge. Equilibrium analysis is therefore not attempted. GHM create a purposefully vague situation onto which subjects project their stable personal tendencies to either cooperate or defect. Since their game differs from ours in this very crucial aspect, as expected, their behavioral results also differ from ours and do not allow direct comparison.

²² The use of integer amounts discretizes the strategy space, but does not change the results. See Appendix A for a discussion on the effects of discretizing the strategy space into unit tokens.

Group assignment. In each round, after all subjects had made their investment decisions, they were partitioned in three groups of four. The four highest investors to the public account were put into one group, the fifth through the eighth highest investor into a second group, and the four lowest investors into a third group. Ties were broken at random. After grouping, subjects' earnings were calculated based on the group to which they had been assigned. Note that group assignment depended only on the subjects' *current* contributions in that round, not on contributions in previous rounds. Subjects were regrouped according to these criteria in each decision round. See Appendix B for full instructions.

End-of-round feedback. After each round, each subject's computer displayed her private and public investment in that round, the total investment made by the group she had been assigned to, and her total earnings. The screen also displayed an ordered series of the group account contributions by all participants in that round, with a subject's own contribution highlighted so that she could see her relative standing. This ordered series was visually split into three groups of four, which further underscored that participants had been grouped according to their contributions and that any ties had been broken at random.

III.B. RESULTS

The main purpose of this analysis is to establish whether the TBM is an effective mechanism that is, whether its near-efficient equilibrium is coordinated in the aggregate. (Results 1-4). Additionally, we report indications of a behavioral MPCR effect, and briefly mention how individual behavior relates to the observed aggregate outcomes.

Result 1

The TBM leads to high and stable contributions.

The solid lines in Figure 2 display mean public account contributions per MPCR and per round. Contributions are high and stable over all 80 rounds. Mean contributions over four sessions and 80 rounds are 70.1 out of 100 possible tokens for MPCR = 0.3 and 83.8 out of 100 for MPCR = 0.5.

Result 2

Observed mean contributions correspond to mean contributions in the near-efficient equilibrium.

The broken lines in Figure 2 represent mean contributions in the near-efficient equilibrium (75 out of 100 tokens for MPCR = 0.3, 83.3/100 for MPCR = 0.5). Observed mean contributions per round (solid lines) closely trace the predicted values. This pattern also emerges in the single sessions. See Table 1 for means per session. The paths of single sessions over trials (Figure 3) resemble their aggregate pattern in Figure 2. As expected, mean contributions under MPCR = 0.3 are significantly lower than under MPCR = 0.5.²³

Result 3

Strategies that are part of the near-efficient equilibrium were predominantly selected.

The near-efficient equilibrium consists of the two corner strategies from among a set of 101 choices. Figure 4 displays the percentages in which choices occurred, by MPCR. Under both MPCRs, subjects predominantly selected corner strategies. 83% of choices under MPCR = 0.5 and 56% of choices under MPCR = 0.3 are exact corner strategies. Choices closely neighboring the exact corner strategies are also somewhat more frequent in particular under MPCR = 0.3. If one classifies choices ≥ 98 as full contribution, and choices ≤ 2 as non-contribution in accordance with both the prominence hypothesis

²³ Mann-Whitney-U-test: $U = 0$ ($n_1 = n_2 = 4$), $p = 0.014$ (1-tailed). The unit of observation is one session.

(Selten, 1997) that people tend to make their choices in multiples of five, and the argument about neighboring strategies by Erev and Roth (1998), 86 % of all choices under MPCR = 0.5, and 66% of choices under MPCR = 0.3 are corner strategies. Clearly, corner strategies were selected with greater precision under MPCR = 0.5 than under MPCR = 0.3. Further below we address these percentage differences between MPCRs when pure counts are used, and why under MPCR = 0.3 neighboring strategies are more frequent.

Result 4

The aggregate proportions in which equilibrium strategies were selected are very close to the near-efficient equilibrium.

In the near-efficient equilibrium ten out of twelve participants (83.3%) make a full contribution under MPCR = 0.5, and nine out of twelve under MPCR = 0.3, while the remainder contributes nothing. See the broken lines in Figure 5. The figure's solid lines display the respective observed percentages per round and per MPCR, with choices ≥ 98 classified as full contribution and choices ≤ 2 classified as non-contribution. Within a few trials subjects reach close-to-equilibrium proportions. Figure 6 confirms this aggregate pattern for every single session even though the pattern is somewhat less pronounced under MPCR = 0.3, particularly in Session 0.3-1.

Additional findings:

Behavior is closer to equilibrium under MPCR = 0.5 than under MPCR = 0.3.

In order to test how close to the equilibrium the behavior in each single round is, we counted the number of individual contributions which can be *exactly* explained by the equilibrium prediction. If, for example, in a particular round under MPCR = 0.5 (where in the near-efficient equilibrium there are two zero-contributions and ten full contributions) the observed contributions are (0, 0, 0, 2, 75, 100, 100, 100, 100, 100, 100, 100), the number of contributions consistent with the equilibrium is nine (two of the zero-

contributions and the seven full contributions). Table 1 shows that behavior under MPCR = 0.5 is closer to the near-efficient equilibrium than under MPCR = 0.3.^{24 25}

Individual strategies are unsystematic.

Graphs of all individual choice paths over trials can be viewed at

<http://anna.rvik.com/M/indls.pdf>. In each MPCR condition, there are actually $\binom{N}{z}$ near-

efficient equilibrium profiles, since each player can either take the role of a full contributor or of a non-contributor. As Ochs (1999, p.143) states very well, once a specific configuration of mutual best responses is reached, one might reasonably expect that this pattern will be stable over repetitions. Our data show the opposite: While the near-efficient equilibrium organizes aggregate behavior, individual choice paths over trials are diverse and unsystematic. Some subjects stick with one (mostly equilibrium) strategy,²⁶ others alternate, in varying proportions, between the two equilibrium strategies, or between equilibrium strategies and intermediate choices. There is no evidence that individual strategies stabilize with experience, nor is there evidence of mixing.²⁷

²⁴ Mann-Whitney-U-test: $U = 0$ ($n_1 = n_2 = 4$), $p = 0.029$ (2-tailed). The unit of observation is one session.

²⁵ A possibly related behavioral effect occurs in the VCM where the speed of convergence toward the sole equilibrium non-contribution by all depends on the MPCR (see, e.g., Isaac & Walker, 1988; Gunnthorsdottir, Houser & McCabe, 2007). There are two possible reasons for such behavioral MPCR effects, both of which could operate in the TBM as well: **1)** the lower the MPCR the less of a difference there is between the individual payoff when everybody contributes and the individual payoff when nobody contributes. For a TBM this means that the lower the MPCR the less of a difference there is between the equilibrium of non-contribution by all and the near-efficient equilibrium. A low MPCR may therefore generate indifference in TBM participants. **2)** There is ample evidence, starting with Kahneman and Tversky's (1979) seminal work, that people are sensitive to the risk of losses in relation to their original wealth w . In the VCM, the maximum a contributor can lose is $(1-g/n)w$ if she is the sole contributor, while non-contribution guarantees her a payoff of at least w . This logic holds for the TBM as well even though, as Section II.C shows, in terms of expected (ex-ante) payoffs the risk is mitigated by competitive grouping. For ex-post payoffs however the MPCR can have a strong effect if a contributor ends up in a mixed group.

²⁶ 31% of subjects under MPCR=0.5 made a full contribution in ≥ 70 of the 80 trials. Under MPCR = 0.3, 21% subjects did. There are hardly any stable non-contributors. If those who contributed ≤ 2 in $\geq 50\%$ of all trials are classified as non-contributors, there are only 6/96 such subjects, all in MPCR = 0.3 (contributing ≤ 2 in 75, 65, 54, 43, 43 and 40 trials, respectively).

²⁷ Under the experiment's parameters, two mixed-strategy equilibria consisting of corner strategies exists for MPCR=0.5, where either $p(x_i=100) = 0.883$ or $p(x_i=100) = 0.117$. None exists for MPCR=0.3. Yet in both conditions aggregate behavior is well accounted for by the near-efficient pure strategy equilibrium. While under MPCR=0.5 the pure strategy equilibrium proportion of 83.3% for $(x_i=100)$ happens to be close to the mixed-strategy equilibrium probability of $p(x_i=100) = 88.3\%$, aggregate behavior is clearly closer to the pure

III.C RELATED EXPERIMENTAL RESULTS

Coordinating a complex asymmetric equilibrium. We have seen that the TBM's asymmetric equilibrium is reliably coordinated in the aggregate even though individual choices over trials are unsystematic. A related phenomenon has frequently been reported in experiments with Market Entry games (henceforth, MEG) (Selten & Guth, 1982; Gary-Bobo, 1990; see Ochs, 1999 for an overview of their behavioral results). In MEGs, too, an asymmetric equilibrium is coordinated apparently "without learning and communication" (Camerer & Fehr, 2006, p. 50) while individual-level data are unsystematic (see, e.g., Rapoport, Seale & Winter, 2002; Erev & Rapoport, 1998; Duffy & Hopkins, 2005). Kahneman (1988, p. 12) calls this phenomenon "magical". Note however that the TBM is much more complex than Market entry games since: **1)** the strategy space in Market Entry games is usually only binary (enter/stay out), **2)** the MEG's asymmetric equilibrium is quite obvious even to a lay person, while the TBM's near-efficient equilibrium is neither obvious nor particularly intuitive, **3)** in the TBM the choice among Pareto-ranked equilibria presents an additional dimension along which participants must coordinate. Hence, to our knowledge, TBM subjects display more complex coordination and "magic" than hitherto observed in experiments.

Coordinating the payoff-dominant equilibrium. It is by no means a common experimental result that, in games with Pareto ranked equilibria, the payoff dominant equilibrium is reliably selected. See for example the much-replicated results by Van Huyck, Battalio & Beil, (1990, 1991) on Weakest-Link games (henceforth, WLG), (see Ochs, 1995;1999, and Devetag & Ortmann, 2007 for overviews), or Step-level VCMs (see,

strategy equilibrium proportions (see Figure 2 and Results 2 and 4). Further, examining individual-level behavior, even though many subjects change their strategy frequently over trials, only 5/48 participants under MPCR=0.5 randomize (individual runs tests, normal approximation, $p=0.05$, 2-tailed) in proportions consistent with $p(x_i=100)=0.883$ (individual Chi-Square tests of goodness of fit, see, e.g., Siegel & Castellan, 1988, $p=0.05$) (The latter test assumes independent random sampling. For the subjects who apparently behave randomly, the test is appropriate).

e.g., Isaac, Schmitz & Walker, 1989). There are two possible reasons why, in contrast, the TBM's payoff-dominant equilibrium emerges so steadily: one reason is structural, the other psychological.

Structural stabilizing aspects. Regarding structural aspects, Step-level VCMs, WLGs, and the TBM all share the feature that their least efficient equilibrium is risk dominant. However, as discussed in Section II.C, a full contributor's risk in the TBM's near-efficient equilibrium is much less than in WLGs or Step-Level VCMs (in the latter games even a small deviation by a single player reduces the earnings of contributors significantly).

Psychological impact of competitive group membership on equilibrium selection. Turning now to the psychological factors that are likely to support the TBM's near-efficient equilibrium, coordination games boil down to expectations. As Harsanyi and Selten (1988, emphasis added) put it, "...[players] should *trust* each other to play [the payoff-dominant equilibrium strategy]." The TBM's competitive group membership probably creates mutual expectations that contributions will be high:

First, competitive group membership generally raises contributions. In VCMs competitive group membership increases contributions well above its equilibrium of non-contribution by all (see, e.g., Cabrera, Fatas, Lacomba & Neugebauer, 2007; Page, Putterman & Unel, 2006; Croson, Fatas & Neugebauer, 2007) while in WLGs it facilitates coordination of a Pareto-superior equilibrium. (Fatas, Neugebauer & Perote, 2006; Croson, Fatas & Neugebauer, 2007).²⁸ There can be several reasons for this: **1)** Humans generally tend to react to competitive situations by competing (see, e.g., Shogren, 1996 for competition effects in an entirely different environment) **2)** More specific to a TBM

²⁸ The literature on the effects of ostracism and endogenous group formation is also somewhat relevant. See Maier-Rigaud, Martinsson & Staffiero, 2005, for a good overview on ostracism; For endogenous group formation, see, e.g., Ahn, Isaac & Salmon, in press)

setting, competitive grouping based on contributions reassures reciprocal cooperator types who contribute as long as others do likewise (see, e.g., Gächter & Thoni 2005).

Second, we suppose that our experimental subjects, like everyone, have observed the effects of competition and competitive organizational membership on their own behavior and the behavior of others. Therefore, in addition to the direct impact of competition on behavior, common knowledge of its effects probably changes expectations and further encourages contributions and, in the case of the TBM, the coordination of the payoff dominant equilibrium.

MPCR effects: The near-efficient equilibrium is slightly better coordinated under $MPCR=0.5$ than under $MPCR=0.3$. Behavioral MPCR effects independent of the equilibrium are well known from the VCM: (see, e.g., Isaac & Walker, 1988; Isaac, Walker & Thomas, 1984, Gunnthorsdottir, Houser & McCabe, 2007). There are two possible reasons for MPCR effects in the VCM, which, somewhat modified, impact the TBM as well: **1)** the lower the MPCR the less of a difference there is between the individual payoff in the Pareto optimum or in the near-efficient equilibrium, and in a situation where nobody contributes. Hence, a low MPCR may generate indifference, and a lack of ambition, in participants. **2)** Sensitivity to the risk of losses in relation to the original wealth w (Kahneman and Tversky, 1979). In the VCM, the maximum a sole contributor can lose is $(1-g/n)w$ while non-contribution guarantees her a payoff of at least w . This fact also holds to some extent for the TBM even though, as Section II.C shows, at least in terms of expected (ex-ante) payoffs the risk is mitigated by competitive grouping. For ex-post payoffs however the MPCR can have a strong effect if a contributor ends up being placed in a mixed group.

IV. DISCUSSION

We present an organization-based production model of society. We find that in the absence of information asymmetries, when contributions are observable and team membership is mobile, it is not so much the nature of the good that affects free-riding incentives, but rather, the team assignment method. We show that the free-riding incentives inherent in the production of team goods can be largely overcome if organizational membership is competitively based upon individuals' contributions.

Our theoretical and experimental results underscore the advantages of a merit-based society above and beyond the obvious: In large societies the efficiency of a Team-Based Meritocracy (TBM) asymptotically approaches the efficiency of an individually based meritocracy. At the same time, a TBM reduces complexity and costs as compared to an individually-based meritocracy, and may contribute to organizational cohesion which in turn enhances competitiveness and overall societal output.

The TBM mechanism is applicable to a wide variety of settings since the nature of the team output is broadly defined and the requirements for a near-efficient equilibrium are not very strict. The empirical confirmation that the TBM's near-efficient equilibrium is easily coordinated in the laboratory adds to our understanding of how societies have become increasingly meritocratic under growing global competition and greater geographic mobility. This paper confirms once more that "much of what social science can demonstrate is already 'known' by evolved social systems" (Dawes et al., 1986, p. 1183).

Our theoretical analysis extends the traditional group-level analysis of team goods to an analysis of a broadly defined social network in which members compete for inclusion in organizational strata that vary in collective payoff. We find that such competitive social stratification has a complex, counterintuitive equilibrium. Our experimental results underscore the predictive and descriptive power of complex Nash equilibria on the

aggregate level. With its rich strategy set and counterintuitive equilibria, the TBM is particularly demanding on participants with regard to tacit coordination. Yet they somehow manage to reliably coordinate an equilibrium which, we assert, they can neither discover nor properly understand. Yet another fact underscoring the power of the Nash equilibrium is that while highly efficient, the TBM does not lead to full Pareto optimality since a Pareto optimal strategy profile is not an equilibrium.

Criticisms and possible extensions

We have focused on the TBM's efficiency and aggregate-level results. Individual decision strategies remain to be examined in depth, as well as, possibly, an MPCR-related impact of loss aversion. Another natural next step is to examine how sensitive the model is to heterogeneity in the endowment w_i . Any meritocracy explicitly eliminates all determinants of organizational membership that could be due to Rawl's (1971) "lottery of birth" except for unequal ability to contribute, e.g. unequal time or talent. In the current model all players have equal endowments w_i . We do not necessarily regard this as a shortcoming of the present model since in the end abilities are multidimensional, allowing for diverse "bundles" of public contribution of similar overall value.

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APPENDIX A

For the TBM's experimental test (Section III) the strategy space was discretized into integer tokens. Since many social contributions, such as effort, are often not lumpy, and even with regard to monetary contributions, micro-payments are on the increase, discretizing reduces external validity somewhat, but it does not affect the results: The near-efficient equilibrium, which exists in both continuous and discrete cases is the coordinating principle of subject behavior.

In the discrete case there emerge additional low-level asymmetric pure strategy equilibria, consisting of zero contributions and very low contributions. Their number and structure is MPCR dependent.

Reasons for the emergence of low-level equilibria in the discrete case. While the results reported come from a brute-force simulation, the reason for the existence of such low-level equilibria, and for their increased number the lower the MPCR, is intuitive: In the continuous case of the TBM, changing one's contribution by a small ε is essentially costless yet impacts group membership. Changing one's contribution by one unit token, however, is not costless. Hence, if the strategy space is discrete there can emerge stable configurations in which it does not behoove a participant to unilaterally change his contribution by an entire unit token in order to switch groups. This tends to occur if the groups' team products are very similar. Team products are more similar the lower public contributions by other participants are, and the lower MPCR. Therefore, the additional equilibria **1)** emerge more frequently the lower the MPCR and **2)** involve very low public contributions. Tables A-A and A-B list all pure strategy equilibria for the parameters experimentally tested in Section III. It can be verified that there are more low-level equilibria under MPCR=0.3 (Table A-A) than under MPCR=0.5 (Table A-B). The near-

efficient equilibrium, which hold in both the discrete and continuous case, is included in
Rows 16 (MPCR=0.3) and 20 (MPCR=0.5).

Table A-A

Equilibria for $N=12$, $n=4$, $w_i = 100$, and MPCR=0.3. Discrete integer strategy space.

(Equilibria in shaded rows hold both in the discrete and continuous case)

	Strategy Configuration ($s_{12}, s_{11}, \dots, s_1$) (Expected payoff per strategy in parentheses)	Efficiency **
1	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 (100.00)	0.0
2	0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1 (100.10) (100.02)	0.4
3	0, 0, 0, 0, 0, 0, 0, 2, 2, 2, 2, 2 (100.39) (100.78)	0.8
4	0, 0, 0, 0, 0, 0, 0, 3, 3, 3, 3, 3 (100.40) (100.06)	1.3
5	0, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1 (100.30) (100.10)	0.7
6	0, 0, 0, 1, 1, 1, 1, 2, 2, 2, 2, 2 (100.30) (100.20) (100.22)	1.1
7	0, 0, 0, 1, 1, 1, 2, 2, 2, 2, 2, 2 (100.30) (100.30) (100.28)	1.2
8	0, 0, 0, 2, 2, 2, 2, 2, 2, 2, 2, 2 (100.60) (100.20)	1.5
9	0, 0, 0, 2, 2, 2, 2, 4, 4, 4, 4, 4 (100.60) (100.40) (100.44)	2.3
10	0, 0, 0, 2, 2, 2, 2, 5, 5, 5, 5, 5 (100.60) (100.62) (100.40)	2.7
11	0, 0, 0, 3, 3, 3, 3, 3, 3, 3, 3, 3 (100.90) (100.30)	2.3
12	0, 0, 0, 4, 4, 4, 4, 4, 4, 4, 4, 4 (101.20) (100.40)	3.0
13	0, 0, 0, 5, 5, 5, 5, 5, 5, 5, 5, 5 (101.50) (100.50)	3.8
14	0, 0, 0, 6, 6, 6, 6, 6, 6, 6, 6, 6 (101.80) (100.60)	4.5
15	0, 0, 0, 7, 7, 7, 7, 7, 7, 7, 7, 7 (102.10) (100.70)	5.3
16	(0, 0, 0, 100, 100, 100, 100, 100, 100, 100, 100, 100) (130.00) (110.00)	75.0

** $\sum_{i=1}^N s_i / Nw$

Table A-B

Equilibria for $N=12$, $n=4$, $w_i = 100$, and $MPCR=0.5$. Discrete integer strategy space.

(Equilibria in shaded rows hold both in the discrete and continuous case)

	Strategy Configuration ($s_{12}, s_{11}, \dots, s_1$) (Expected payoff per strategy in parentheses)	Efficiency**
17	(0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0) (100.00)	0.0
18	0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 (101.00) (100.80)	0.7
19	0, 0, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2 (102.00) (101.60)	1.5
20	0, 0, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100 (200.00) (180.00)	83.3

$$** \sum_{i=1}^N s_i / Nw$$

APPENDIX B

Instructions

This is an experiment in the economics of group decision-making. You have already earned \$7.00 for showing up at the appointed time. If you follow the instructions closely and make decisions carefully, you will make a substantial amount of money in addition to your show-up fee.

There will be many decision-making periods. In each period, you are given an endowment of 100 tokens. You need to decide how to divide these tokens between two accounts: a **private** account and a **group** account.

Each token you place in the **private** account generates a cash return to you (and to you alone) of 1 cent.

Tokens that group members invest in the **group** account will be added together to form the group investment. The group investment generates a cash return of 2 cents per token. These earnings are then divided equally between group members. Your group has 4 members (including yourself).

Returns from the group investment are illustrated in the table below. The left column lists various amounts of group investment; the right column contains the corresponding personal earnings for each group member.

Returns from the Group Investment

*Total investment by
your group*

*Return to each group
member
(From group investment)*

0	0
20	10
40	20
60	30
100	50
150	75
200	100
300	150
400	200

Example:

Assume that, in a specific period, your endowment is 100 tokens. Assume further that you decide to contribute 50 tokens to your private account and 50 tokens to the group account. The other group members together contribute an additional 250 tokens to their group accounts. That makes the group investment 300 tokens, which generates 600 cents ($300 * 2 = 600$). The 600 cents are then split equally among the 4 group members. Therefore, each group members earns 150 cents from the group investment ($600/4=150$). In addition to

earnings from the group account, each member gets 1 cent for every token invested in his/her private account. As you invested 50 tokens in the private account, your total profit in this period is $150 + 50 = 200$ cents.

Each period proceeds as follows:

First, decide on the number of tokens to place in the private and in the group account, respectively. Use the mouse to move your cursor to the box labeled “Private Account”. To make your private investment, click on the box and enter the number of tokens you wish to allocate to this account. Do likewise for the box labeled “Group Account”. Entries in the two boxes must sum to your endowment. To submit your investment click on the “Submit” button. You will then wait until everyone else has submitted his or her investment decision.

Second, once everyone has submitted his or her investment decision, you will be assigned to a group with 4 members (including yourself). **This assignment will proceed in the following manner:** participants' contributions to the group account will first be ordered from the highest to the lowest. Then the four highest contributors will be grouped together. Participants whose contributions ranked from 5-8 will form another group. Finally, the four lowest contributors will form the third group. Any ties that may occur will be broken at random. Experimental earnings will be computed *after* you have been assigned to your group. Thus, your contribution to the group account in a specific round affects which group you are assigned to in that round.

Third, you will receive a message with your experimental earnings for the period. This information will also appear in your Record Sheet at the bottom of the screen. The record sheet will also show the group account contributions by all participants in the experiment, including yours, in ascending order. Your contribution will be highlighted.

A new period will begin after everyone has acknowledged his or her earnings message.

After the last period, you will receive a message with your total experimental earnings (sum of earnings in each period).

This is the end of the instructions.

Table 1**Strategy choices by MPCR and by session**

Session #	MPCR = 0.3				
	1	2	3	4	Total
Mean contribution	65.1%	71.2%	71.7%	72.3%	70.1%
# full contributors	19.0%	45.5%	57.8%	57.1%	44.8%
# zero contributors	14.2%	10.1%	4.2%	15.2%	10.9%
# contributions consistent /w equilibrium	32.8%	55.5%	62.0%	70.8%	55.3%

Session #	MPCR = 0.5				
	1	2	3	4	Total
Mean contribution	86.1%	83.1%	81.3%	84.9%	83.8%
# full contributors	82.3%	76.3%	72.3%	73.3%	76.0%
# zero contributors	4.9%	10.9%	7.8%	4.6%	7.1%
# contributions consistent /w equilibrium	84.3%	84.9%	78.8%	77.7%	81.4%

Figure 1

Impact of deviations on a remaining full contributor's payoff if $N=100$, $n=10$, $MPCR=0.3$

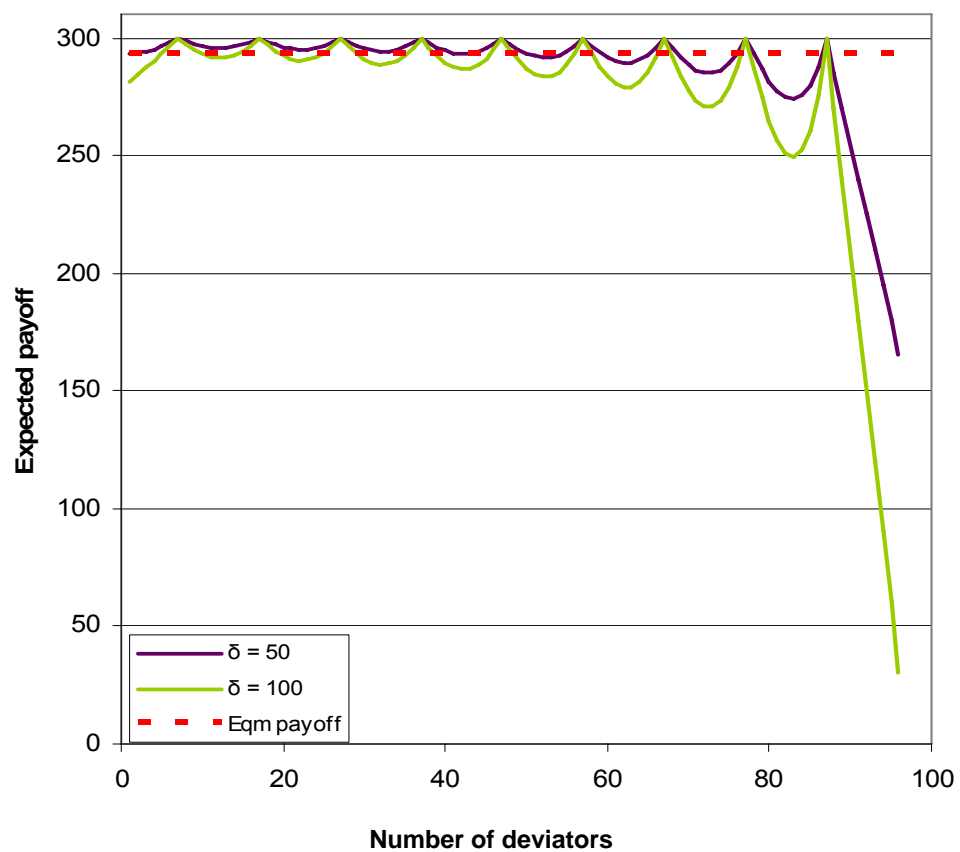


Figure 2

Mean public contributions in the near-efficient equilibrium, and observed mean public contributions per round.

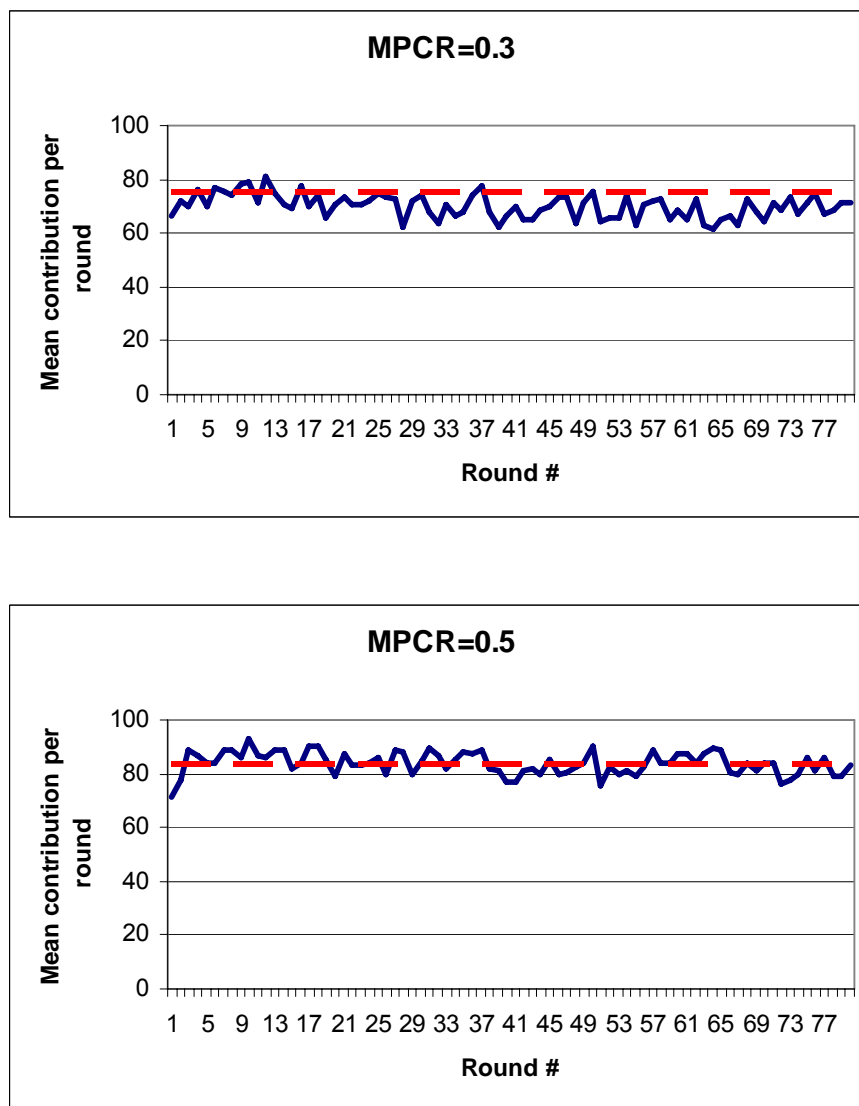


Figure 3A

Observed mean contributions per session and per round, and mean contribution in the near-efficient equilibrium, MPCR=0.3,

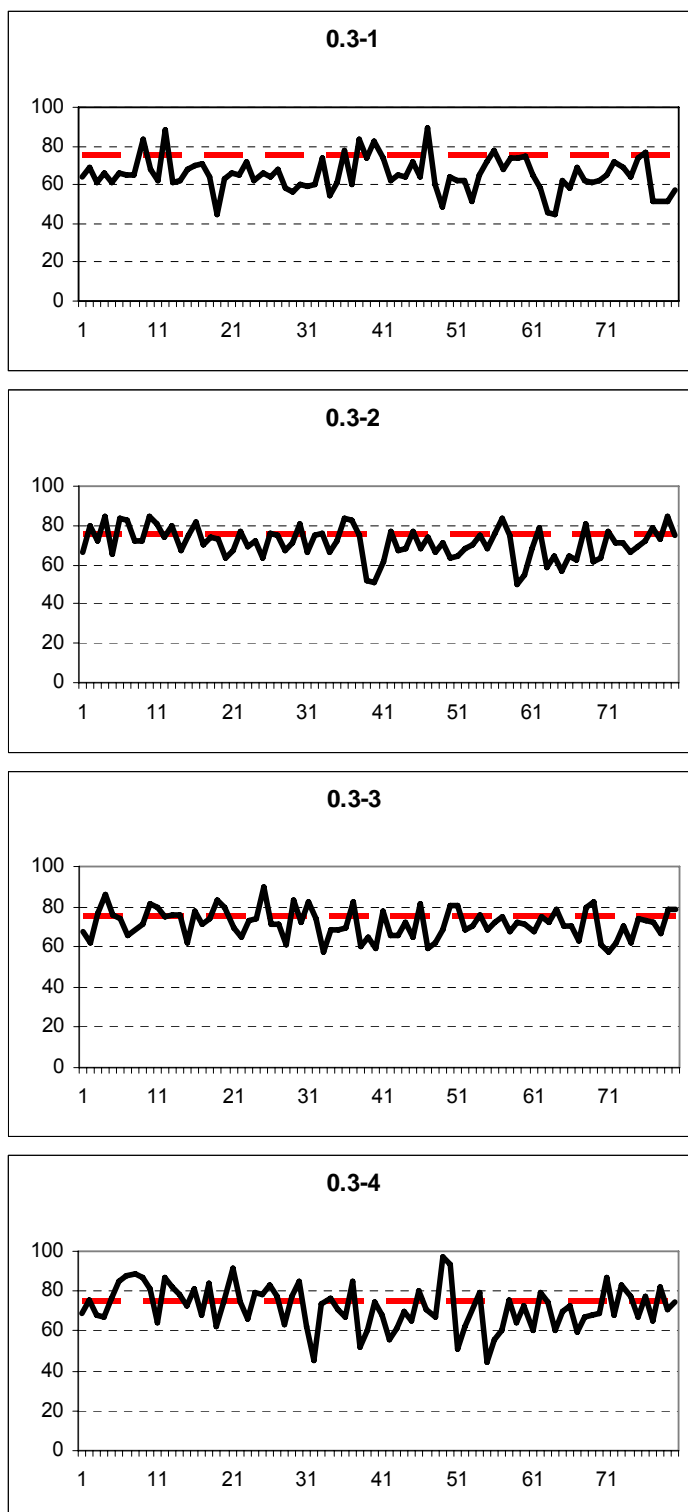


Figure 3B

Observed mean contributions per session and per round, and mean contribution in the near-efficient equilibrium, MPCR=0.5

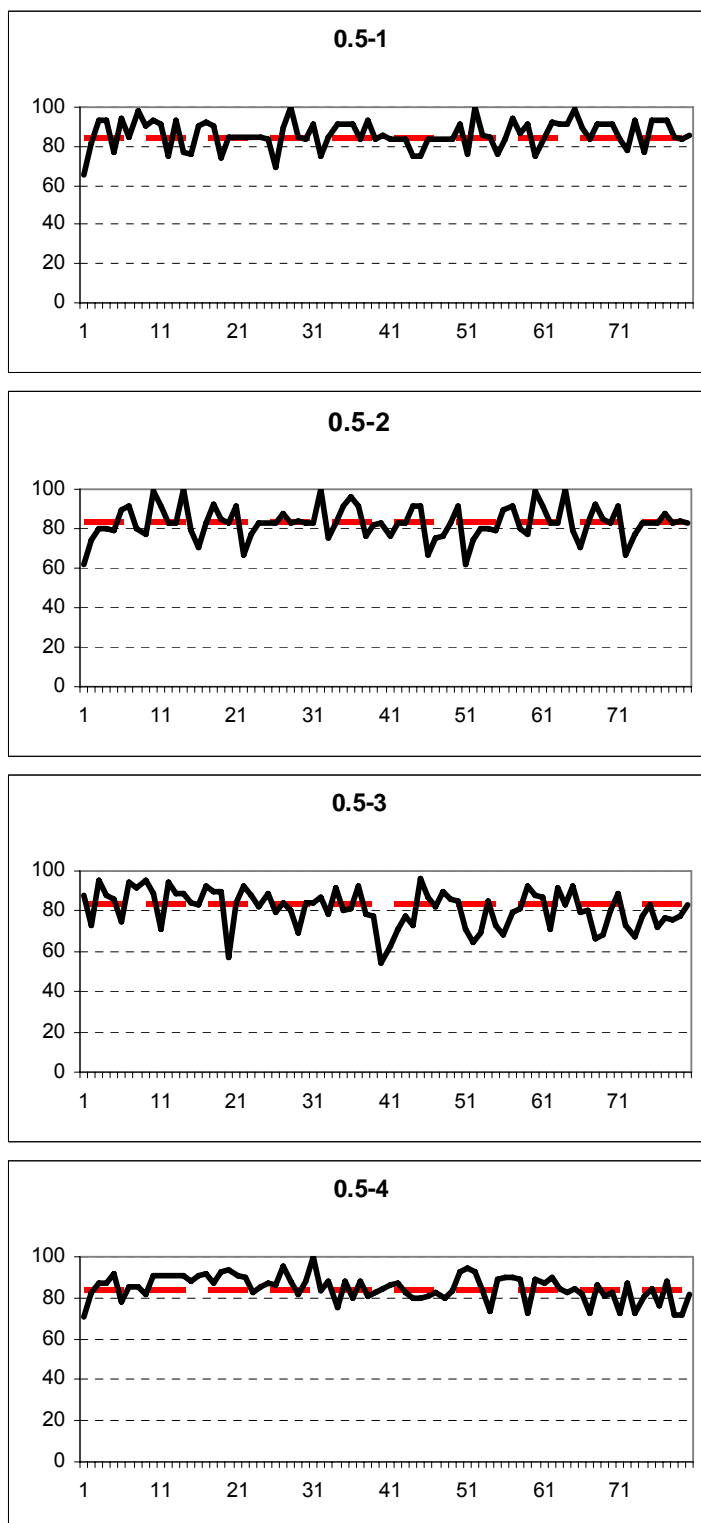


Figure 4

Relative frequency at which each strategy was chosen, by MPCR

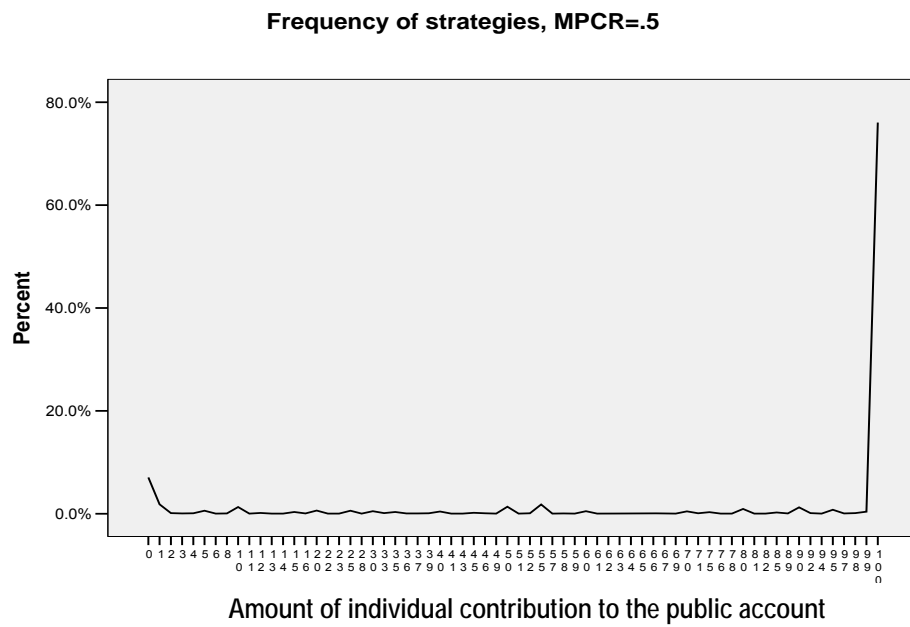
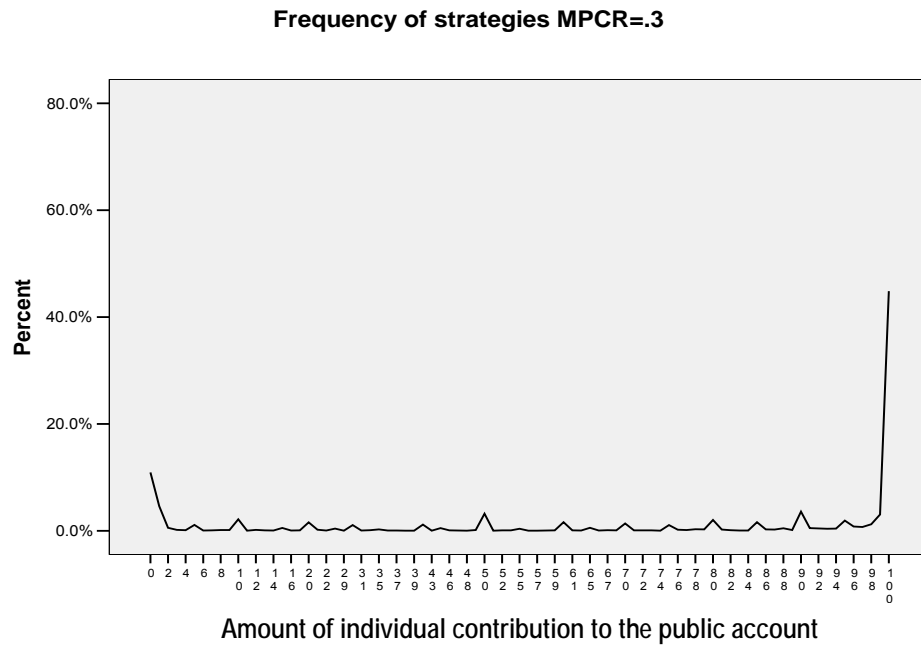


Figure 5
Observed proportions and equilibrium proportions of zero and full contributions
per round, by MPCR

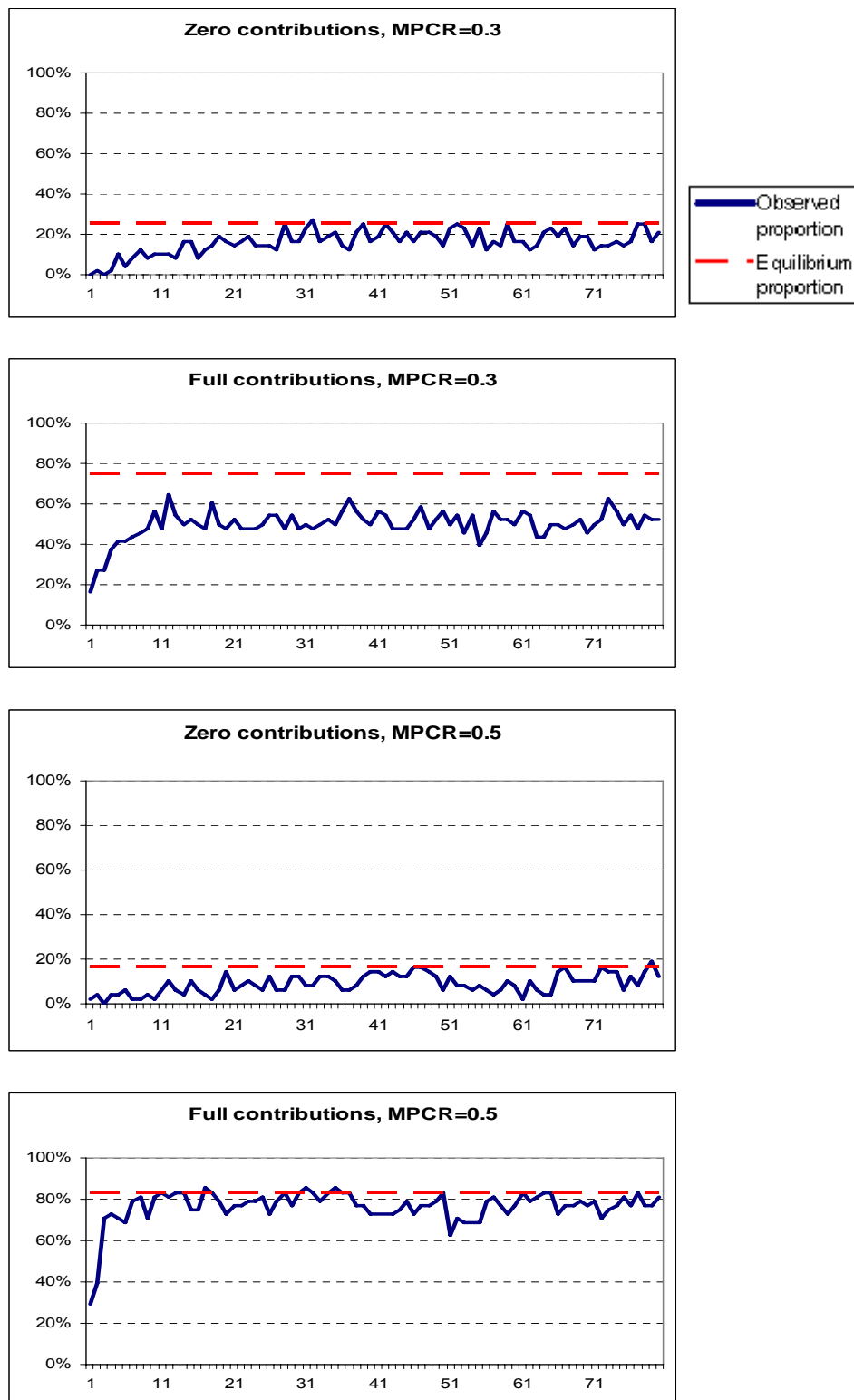


Figure 6 A

Raw frequencies per session MPCR=0.3

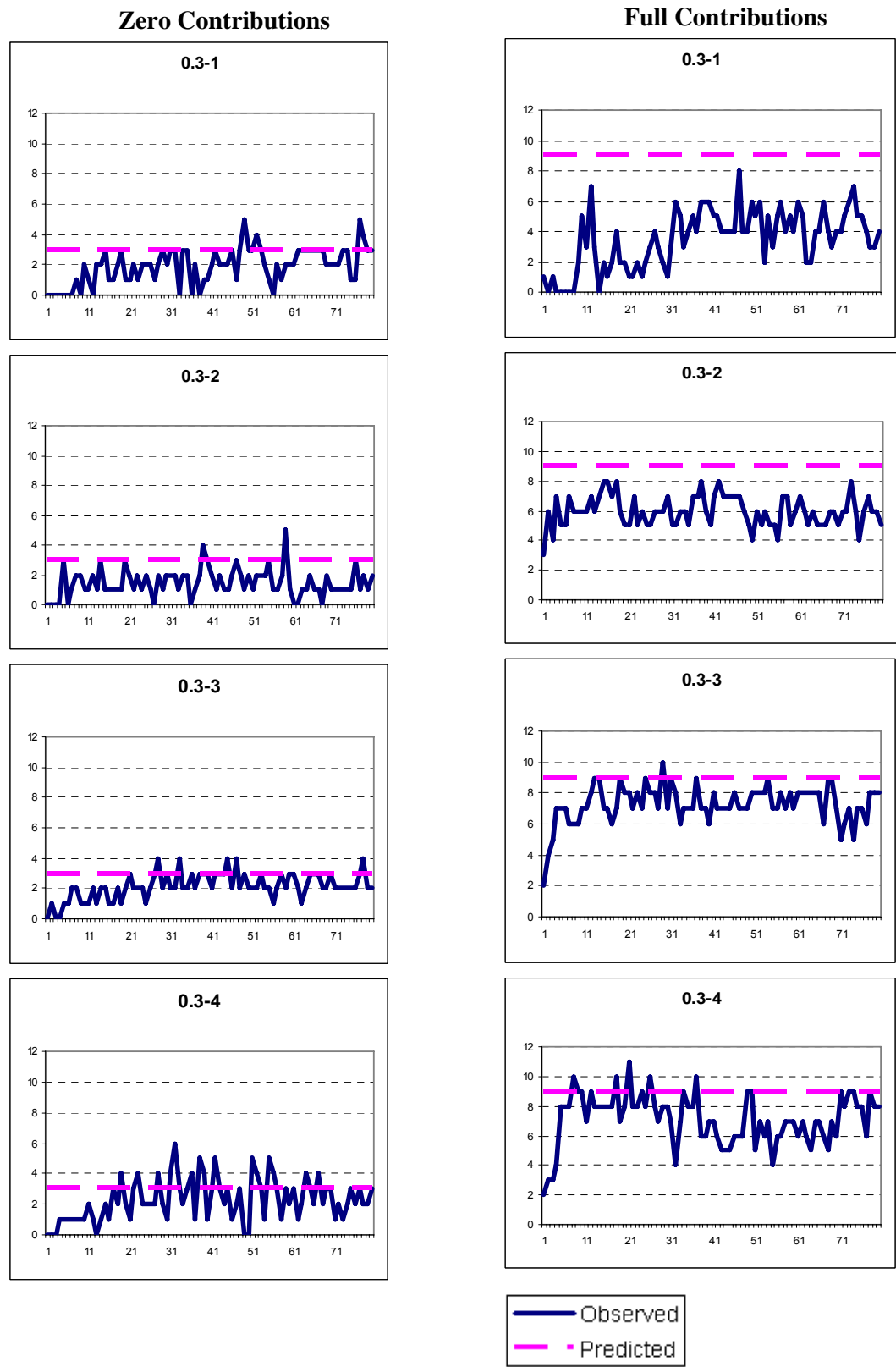


Figure 6 B**Raw frequencies per session. MPCR=0.5**